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A Synopsis of the Potential Use of miRNAs as Forensic Biomarkers in the Identification of Traumatic Brain Injury

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Introduction

Traumatic Brain Injury (TBI) is a complex medical condition resulting from external force trauma to the head, leading to disruption of normal brain function. It encompasses a spectrum of injuries, ranging from mild concussions to severe, life-threatening trauma. According to the World Health Organization (WHO), TBI is a leading cause of death and disability worldwide, particularly among young adults and the elderly. The incidence of TBI is influenced by various factors, including accidents, sports-related injuries, falls, and assaults. One of the critical challenges in managing TBI is the timely and accurate diagnosis of the injury's severity. Traditional diagnostic methods, such as imaging techniques like CT scans and MRIs, provide valuable information but may not capture the full extent of damage or predict long-term outcomes accurately. Additionally, these methods are often expensive, time-consuming, and require specialized equipment and expertise [1].

In recent years, there has been growing interest in identifying biomarkers that can aid in the diagnosis, prognosis, and monitoring of TBI. Biomarkers are measurable indicators of biological processes or responses to disease or injury. They can be molecules such as proteins, nucleic acids, or small molecules found in bodily fluids like blood, saliva, urine, and Cerebrospinal Fluid (CSF). The search for reliable biomarkers for TBI has led researchers to explore the potential of microRNAs (miRNAs) as valuable tools in forensic investigations related to TBI [2].

Description

MiRNAs are small non-coding RNA molecules that play crucial roles in post-transcriptional gene regulation. They function by binding to messenger RNA (mRNA), thereby influencing gene expression by either promoting mRNA degradation or inhibiting its translation into proteins. MiRNAs are involved in various biological processes, including cell proliferation, differentiation, apoptosis, and synaptic plasticity in the brain. MiRNAs are remarkably stable in various biological fluids, including blood, saliva, urine, and CSF. Unlike other biomolecules that may degrade rapidly, miRNAs can withstand harsh conditions, such as changes in pH or temperature, making them suitable for forensic investigations where sample preservation and handling are critical. Certain miRNAs exhibit tissue-specific expression patterns, including in the brain. Changes in miRNA expression profiles in response to TBI can reflect specific alterations in brain regions affected by the injury, providing insights into the underlying molecular mechanisms and potential therapeutic targets [3].

TBI often triggers neuroinflammatory responses and neuronal damage, leading to secondary brain injury. MiRNAs participate in regulating inflammatory pathways, neuronal survival, and synaptic function, making them valuable indicators of TBI-related pathophysiological processes. Numerous studies have explored the dysregulation of specific miRNAs in association with TBI. For instance, miR-21, miR-124, miR-155, and miR-146a have been implicated in neuroinflammation, neuronal apoptosis, and blood-brain barrier dysfunction following TBI. Detection of these miRNAs in biofluids can provide valuable diagnostic and prognostic information regarding TBI severity, progression, and outcomes. MiRNAs can serve as diagnostic markers for TBI, aiding in the rapid and accurate identification of brain injury, particularly in cases where traditional imaging methods may be inconclusive or unavailable. Blood-based miRNA assays offer non-invasive and cost-effective means of TBI detection, making them suitable for forensic investigations and emergency medical settings [4].

Certain miRNAs may serve as prognostic indicators of TBI outcomes, including recovery trajectories, risk of complications such as post-traumatic epilepsy, and long-term cognitive impairment. By analyzing miRNA expression patterns longitudinally, clinicians and forensic experts can assess the progression and resolution of TBI-related pathologies. MiRNA profiles obtained from biological samples, such as bloodstains or CSF, can serve as forensic evidence in legal cases involving TBI-related incidents, such as accidents, assaults, or sports-related injuries. The identification and quantification of specific miRNAs associated with TBI can contribute to establishing the timing, severity, and causative factors of the injury. MiRNAs implicated in TBI pathogenesis represent potential targets for therapeutic interventions. Pharmacological modulation of miRNA activity, either through miRNA mimics or inhibitors, holds promise for developing personalized treatment strategies aimed at mitigating TBI-related complications and promoting neuroregeneration [5].

Conclusion

The potential use of microRNAs (miRNAs) as forensic biomarkers in the identification of Traumatic Brain Injury (TBI) represents a promising avenue for improving diagnostic accuracy, prognostic assessment, and forensic investigations related to TBI cases. MiRNAs offer several advantages, including stability in biological fluids, tissue-specific expression patterns, and regulatory roles in neuroinflammation and neurodegeneration, making them valuable indicators of TBI-related pathophysiological processes. Research efforts focusing on identifying specific miRNA signatures associated with TBI severity, progression, and outcomes are underway, with the goal of translating these findings into clinical practice and forensic applications.

Overall, the integration of miRNA biomarkers into forensic practice holds great promise for enhancing our understanding of TBI mechanisms, improving patient outcomes, and facilitating legal proceedings by providing objective and reliable evidence in cases involving TBI-related incidents. Collaborative efforts among researchers, clinicians, forensic experts, and policymakers are essential to harnessing the full potential of miRNAs as forensic biomarkers in TBI identification and management.

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Conflict of Interest

None.

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